EVALUATION IN DISTURBANCE FORCE COMPENSATION VIA STATE OBSERVER AND CONTROLLER DESIGN

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons)

by

PHOO YOONG HAU

B051410106

940223-10-5433

FACULTY OF MANUFACTURING ENGINEERING

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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Sesi Pengajian: **2017/2018 Semester 2**

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I hereby, declared this report entitled “Evaluation in disturbance force compensation via state observer and controller design” is the results of my own research except as cited in reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.).

The members of the supervisory committee are as follow:

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(Associate Prof. Dr. Zamberi Bin Jamaludin)

ABSTRAK

Keperluan asas ketepatan tinggi dan alat mesin yang tepat yang mesti dipenuhi ialah ia dapat memperoleh output yang diingini dengan input yang diberikan. Walau bagaimanapun, selalu ada gangguan yang tidak dijangka berlaku semasa proses pemesinan seperti getaran, geseran dan daya pemotongan yang akan memberi kesan besar kepada ketepatan dan ketepatan pengeluaran pemesinan. Oleh itu, gaya gangguan seperti ini mesti dikompensasi atau dielakkan untuk meningkatkan ketepatan dan ketepatan. Daya gangguan biasanya sukar untuk dianggarkan dan sensor fizikal mempunyai pelbagai kelemahan seperti kos yang tinggi dan mengurangkan kebolehpercayaan. Pemerhatian negara boleh digunakan untuk menggantikan sensor untuk menganggarkan daya gangguan. Matlamat projek ini adalah untuk menganggarkan dan mengimbangi daya gangguan dalam proses penggilingan simulasi melalui pemerhati negara dan reka bentuk pengawal. Pemerhati itu direka berdasarkan kaedah Pritschow (2004) yang membina semula kekuatan gangguan yang berlaku di antara benda kerja dan alat semasa proses pemotongan menggunakan pecutan relatif. Pengawal kedudukan dan pemerhati negara direka bentuk dalam persekitaran MATLAB / SIMULINK. Sistem kawalan dijangka dapat memberi pampasan dengan berkesan daya gangguan input yang dimasukkan dalam bentuk isyarat sinus tunggal dan isyarat multi-sine. Persembahan pengawal diukur berdasarkan kesalahan pengesanan maksimum. Berdasarkan hasil pengesahan, pengamat pasukan telah terbukti dapat mengimbangi gangguan masukan gelombang sinus tunggal dan gangguan masukan gelombang sinus. Oleh kerana kesilapan pengesanan maksimum di antara anggaran isyarat dan gangguan input gelombang sinus tunggal atau gangguan masukan gelombang sinus yang masing-masing mengurangkan 25.00% dan 38.18% apabila isyarat yang diperkirakan dari pemerhati kuasa diterapkan semula ke dalam gelung kawalan.

ABSTRACT

The basic requirement of a high accuracy and precise machine tool that must be met is that it is able to obtain a desired output with the given input. However, there is always some unexpected disturbance occur during the machining process such as vibration, friction and cutting force that will greatly affect the accuracy and precision of the machining output. Thus, this kind of disturbance force must be compensated or avoided in order to enhance accuracy and precision. Disturbance forces are usually hard to estimate and physical sensors have various disadvantages such as high cost and reduce reliability. A state observer may use to replace sensor to estimate the disturbance force. The aim of this project is to estimate and compensate disturbance force in simulated milling cutting process via state observer and controller design. The observer is designed based on the Pritschow (2004) method which reconstructs the disturbance forces that occur between the workpiece and the tool during the cutting process using relative acceleration. The position controller and the state observer are designed in MATLAB / SIMULINK environment. The control system is expected to be able to compensate effectively the input disturbance force that are inserted in the form of single sine signal and multi-sines signal. The controller performances are measured based on maximum tracking errors. Base on the result of analysis, the force observer has been proven that it is able to compensate the both single sine wave input disturbance and multi sine wave input disturbance. As the error between estimated signal and single sine wave input disturbance or multi sine wave input disturbance reduce 25.00% and 38.18% respectively when estimated signal from force observer is applied back into control loop.

DEDICATION

For

My beloved father, PHOO SAI ONN

My beloved mother, CHONG MEI MEI

My adored sister and brother

ACKNOWLEDGEMENT

Completing this final year project report is a large task and requires support from numerous people, and those people deserve thanks. First, I would like to convey my deepest gratitude to my respected supervisor, Associate Prof. Dr. Zamberi Bin Jamaludin. It is a great honour and pleasure to be able completing this final year project under his supervision, who willing to spend his precious time for giving me ideas in and providing intellectual opinions throughout the learning process. Your kind advice, time, attention and dedication towards realizing this project are greatly appreciated and indebted.

Secondly, I would also like to thank my parents and my siblings who supporting me all the time without knowing the meaning of tiredness.

Thirdly, I also would like to thank to my friends who helped me a lot in finalizing this project within the limited time frame.

Last but not least, thank you to everyone who had been a crucial part of realization of this final year project.

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LIST OF ABBREVIATIONS

ADC	-	Analog Digital Converter
ANN	-	Artificial Neural Network
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CIM	-	Computer Integrated Manufacturing
CNC	-	Computer Numerical Control
DAC	-	Digital Analog Converter
DFO	-	Disturbance Observer
DSP	-	Digital Signal Processing
FRF	-	Frequency Response Function
IMBDO	-	Inverse Model Base Disturbance Observer
IoT	-	Internet of Thing
MCU	-	Machine Control Unit
NC	-	Numerical Control
RMSE	-	Root Mean Square Error
SMC	-	Sliding Mode Control

LIST OF SYMBOLS

° C	-	Degree Celsius
$G(s)$	-	Transfer Function
$Y(s)$	-	The table position in micrometer
$U(s)$	-	The input voltage in volts
K_f	-	Motor Constant
K_p	-	Propotional Gain
K_i	-	Integral Gain
V_{est}	-	Estimated Velocity
$\ddot{x}(t)$	-	Absolute acceleration
d	-	Disturbance force
M	-	Constant
F	-	Frictional force
U	-	Input voltage to the drive amplifier

CHAPTER 1

INTRODUCTION

This project is related to the evaluation of disturbance force compensation via state observer and controller design. In this chapter, the background of this project, objectives, problem statements and scope of the project will be discussed. The background of the project discusses the disturbance force presence in CNC machining. One of the current issues that faced by CNC machining is that disturbance force presented will affect the accuracy of the machine tools and the quality of the machined part. The method of reducing the disturbance force present was suggested at the end of this project.

1.1 Project Background

According to Groover (2007), manufacturing industry is one of the greatest engines of the growth of global economy. As the manufacturing industry continues to grow, the number of people involved in this industry has increased dramatically. This cause the competition among the industry to become stiffer. Hence the manufacture attempt to reduce the labor cost, production and produce a high quality and precision product at a low cost in order to survive in this highly competitive environment. This may cause the demand for high precision and quality product getting increased.

As the demand for high precision and quality product are getting increased. The manufacturing technology has undergone a huge development day by day aiming at improving precision, quality, and productivity as well as reducing the production cost. One of the most significant developments in manufacturing technology that meets this requirement is CNC machining.

According to Valentino & Goldenberg (2008), CNC machining was first introduced in the early 1970s, CNC is the automation of machine tools by the method of a computer perform pre-programmed sequences of machine control command. The CNC machining has the advantages of setup time reduction, lead time reduction, contouring of complex shapes, a high degree of accuracy and increase of productivity. There are many different types of CNC machines are used in industry. The majority of them are CNC machining center and CNC lathes.

However, there is some disturbance force that will greatly affect the accuracy and precision of the CNC machining process. Disturbance force is defined as undesired inputs to a system. In this case, the disturbance force is defined as undesired input found in CNC machining. Those disturbance force may know as vibration, frictional force and cutting force. This kind of disturbance force can affect positioning and tracking accuracy of the machine tools. These two factors are important in the precision machining process. Hence, this kind of disturbance force must be compensated.

1.2 Problem Statement

The basic requirement of a high accuracy and precision machine tool that must be met is that it is able to obtain a desired output with the given input. However, there is always some unexpected disturbance occur during the machining process such as vibration, friction and cutting force that will greatly affect the accuracy and precision of the machining output.

For most of the case, direct estimation of disturbance force is impractical. Disturbance forces are usually hard to estimate and physical sensors contain various disadvantages such as increasing cost and reduce reliability. A state observer may use to replace sensor to estimate disturbance force. One of the key advantages of state observer over the sensor is that disturbance signal can often be observed accurately without the addition of sensors. Hence, a state observer is recommended and needed to estimate the disturbance force enter the system while a feedback control scheme is needed to reduce the disturbance. This project is using the relative acceleration in designing the observer.

1.3 Objectives

The objectives of this project are:

1. To design a state observer that estimate disturbance forces entering a system.
2. Applied the estimated state in feedback control loop for disturbance force compensation.
3. To eveluate the effectiveness of the controller and observer.

1.4 Scopes

The scopes of the project are:

1. The state observer is designed based on the idea of Pritschow (2004).
2. The state observer is designed and simulated using Simulink.
3. The controller is designed and simulated using MATLAB / SIMULINK.
4. The disturbance forces in this project are limited to single sine wave and multi sine wave.

1.5 Organization of Report

This report is consists of five chapters. The first chapter covers the introduction of the report. It generally explains the background of the project, problem statement, objective and scope of the project.

Chapter two consists of the literature review. This chapter summarizes a critical and comprehensive review of the literature related to the topic which included the state observer, controller, disturbance force compensation. It is a critical, analytical summary and synthesis of the current knowledge of a topic. The literature review will be done based on a journal article, book, internet resources, and previous studies. Based on the information gathered, this chapter will give the main points of each book or pertinent findings of a journal article, explain how it relates to the topic.